Relationships of Dust Aerosol with the AMO and Hurricanes

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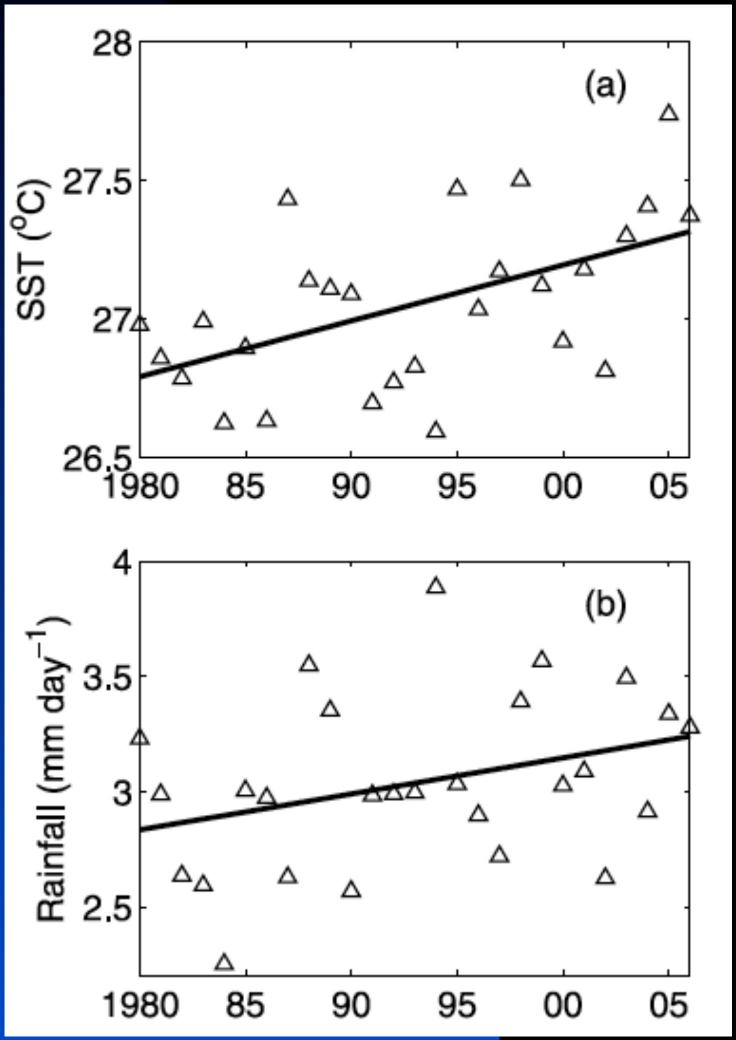
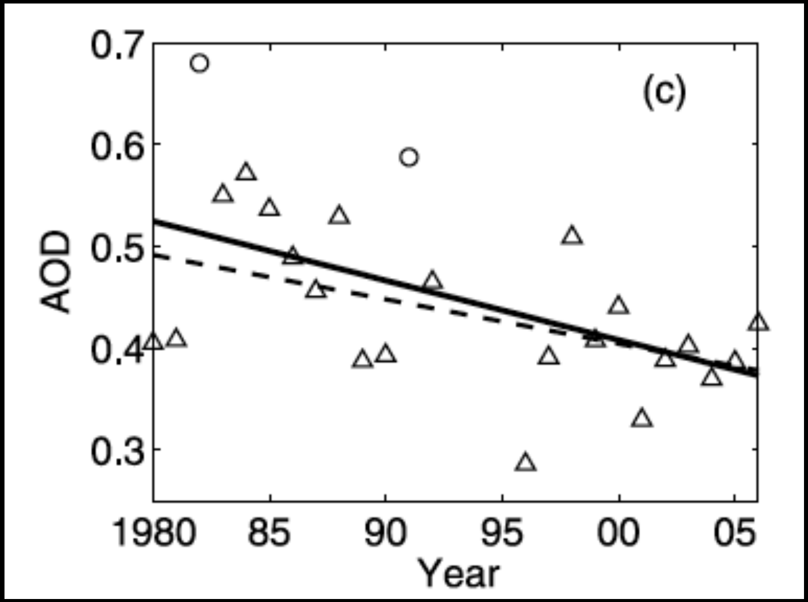
Wang, C., S. Dong, A. T. Evan, G. R. Foltz, and S.-K. Lee, 2012: Multidecadal covariability of North Atlantic sea surface temperature, African dust, Sahel rainfall and Atlantic hurricanes. *J. Climate*, 25, 5404-5415.

Atlantic Oceanographic & Meteorological Laboratory
National Oceanic & Atmospheric Administration

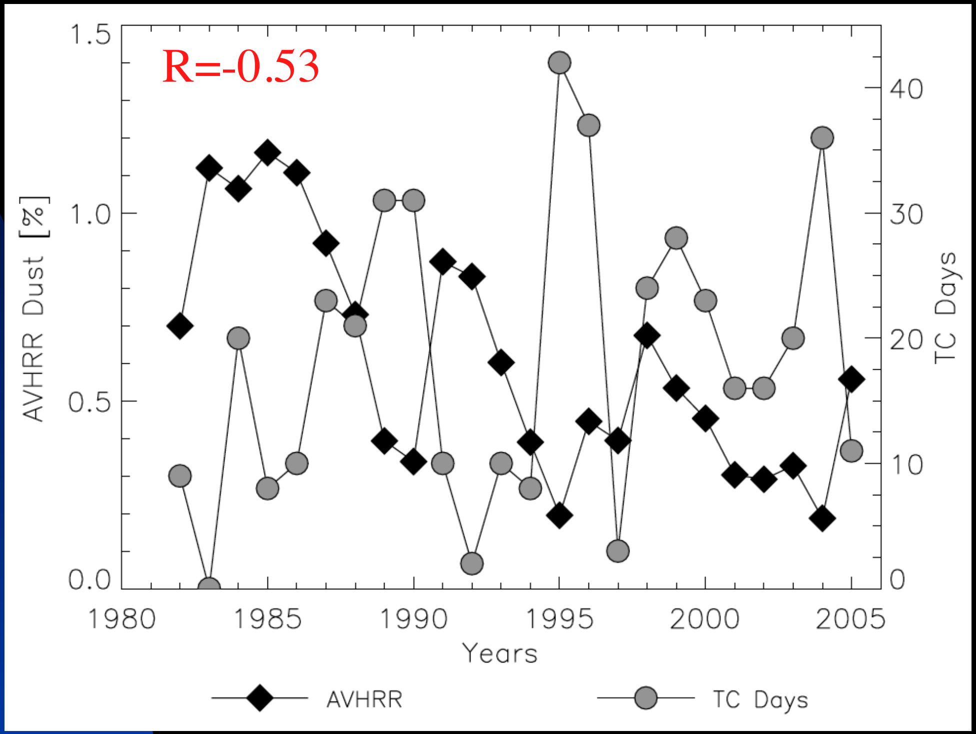
Climate: **Previous studies have limited to a short period since the satellite era (1980 onward), precluding the examination on longer timescales.**





The data from 1980-2006 show trends of Sahel rainfall and dust during the most recent upswing of the AMO (Foltz & McPhaden 2008, *GRL*).

Hurricanes: Previous studies have limited to a short period since the satellite era (1980 onward), precluding the examination on longer timescales.

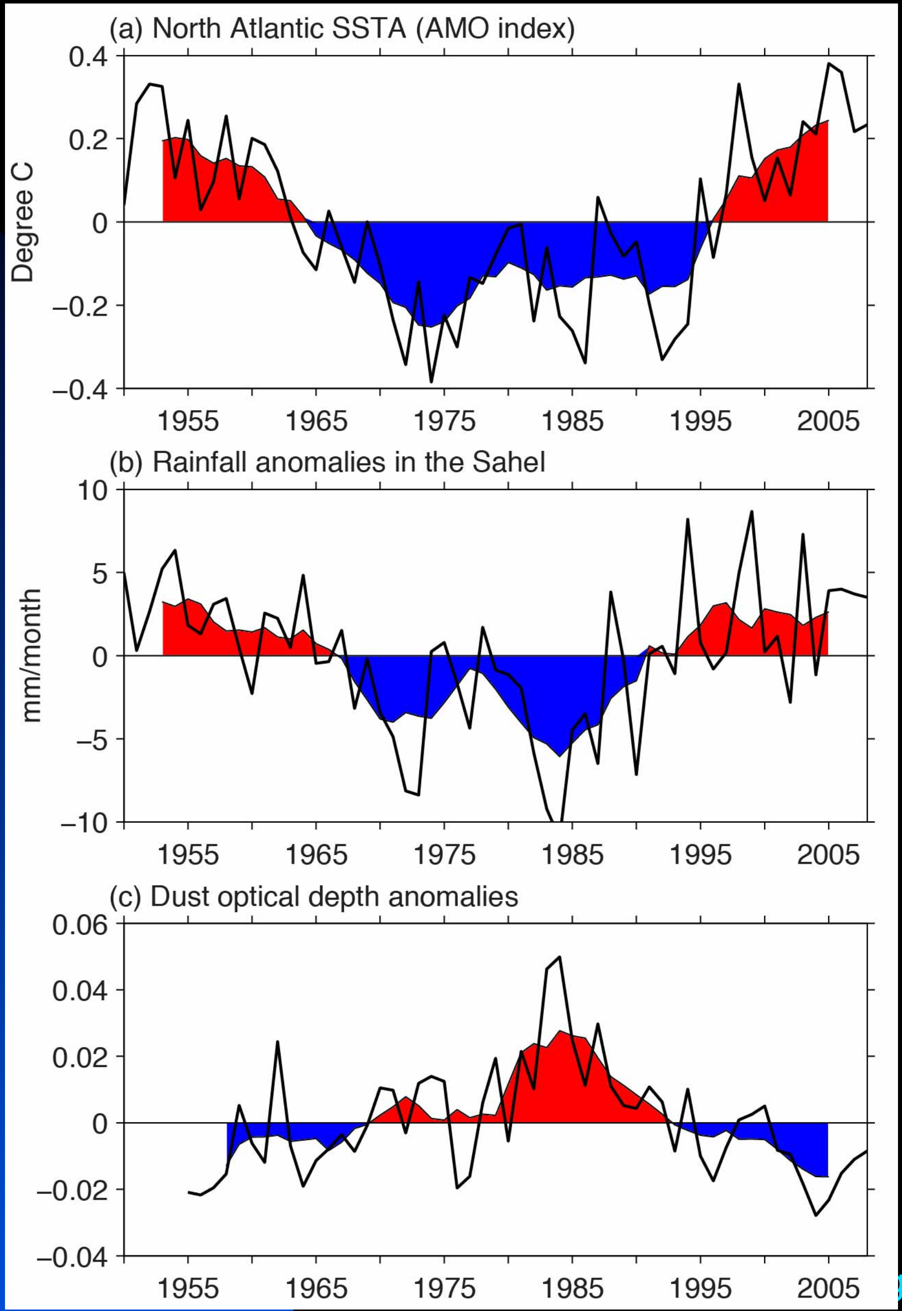


Evan et al. (2006, *GRL*) have demonstrated a negative relation between interannual variations in Atlantic TC days and dust measured by satellite during 1982-2005.

Data Sets Used in This Study

- **Dust data from 1955-2008 (Evan and Mukhopadhyay 2010): A combination of modern/historical data and a proxy record (crustal ^4H_e from a Porites coral) for atmospheric dust.**
- **Extended Reconstructed SST (ERSST) version 3.**
- **NCEP-NCAR reanalysis.**
- **ERA-40 reanalysis.**
- **The 20th Century Reanalysis (20CR).**
- **Wind station data observed in the Western Sahel.**
- **Global Precipitation Climatology Centre (GPCC).**
- **Hurricane data based on HURDAT reanalysis.**

Co-variability of the AMO, dust and Sahel rainfall

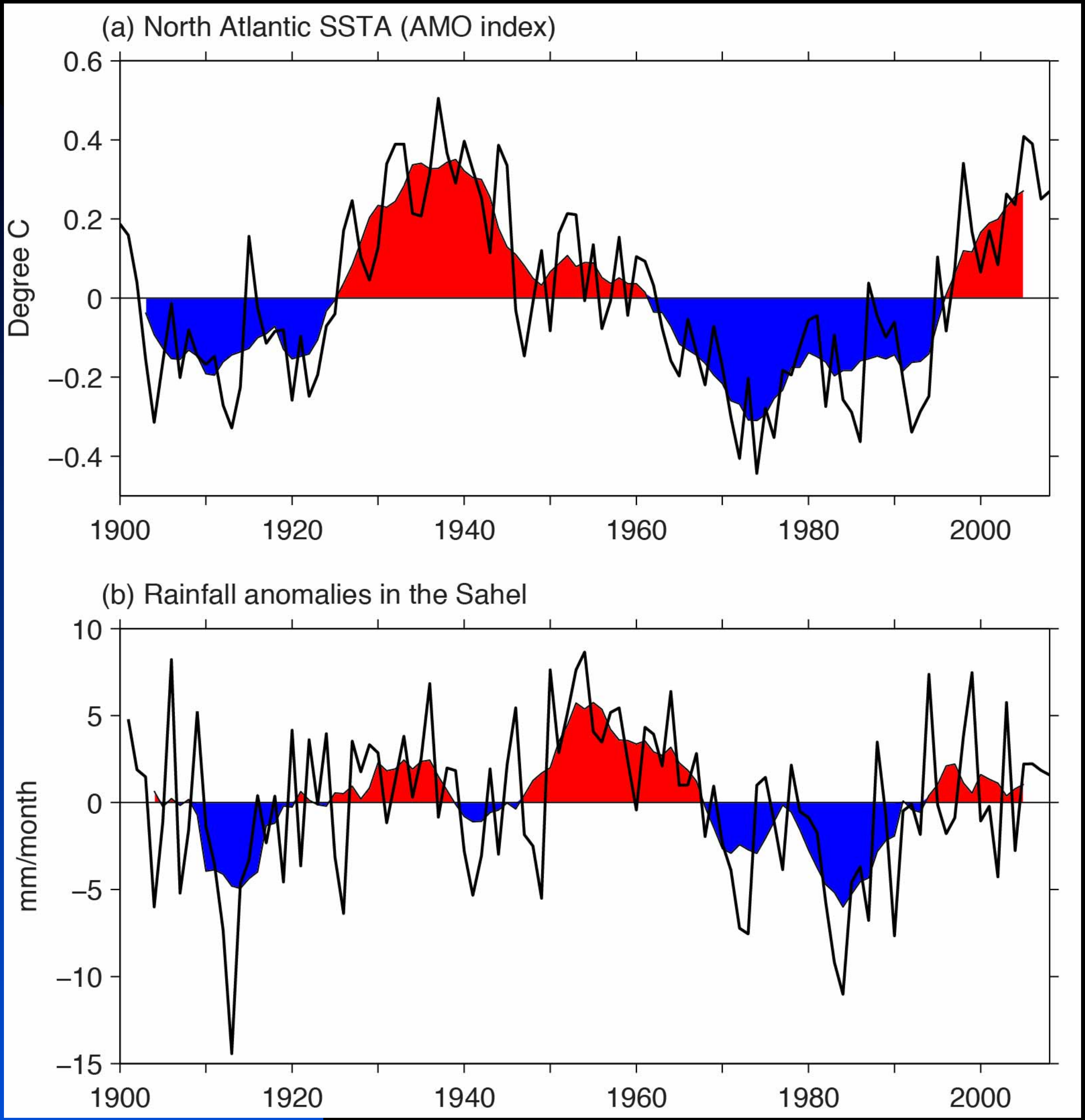


Atlantic Multidecadal Oscillation (AMO)

Sahel rainfall

Dust in the tropical North Atlantic (TNA)

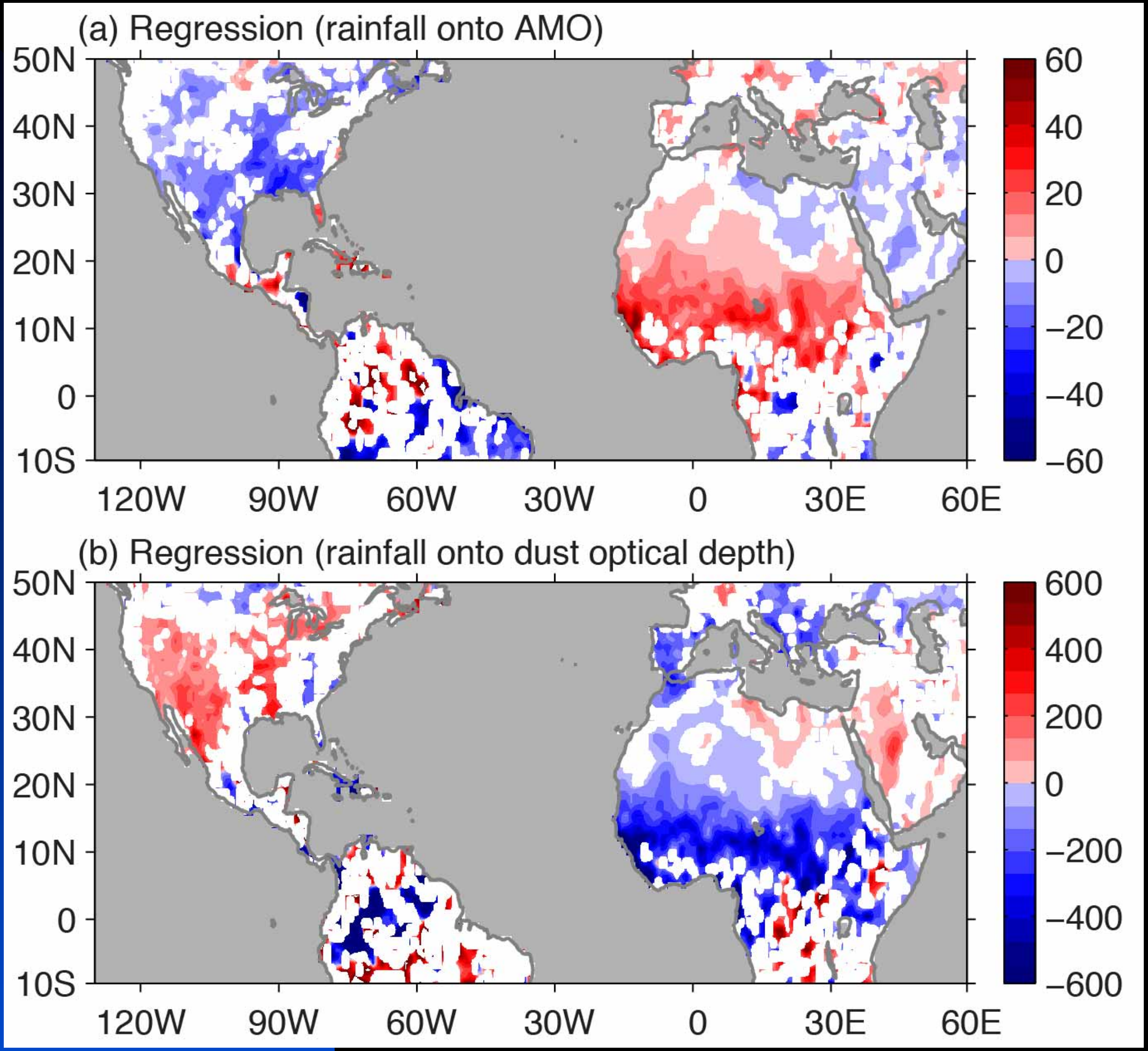
The AMO-Rainfall relation still holds for the entire 20th century



AMO

Sahel rainfall

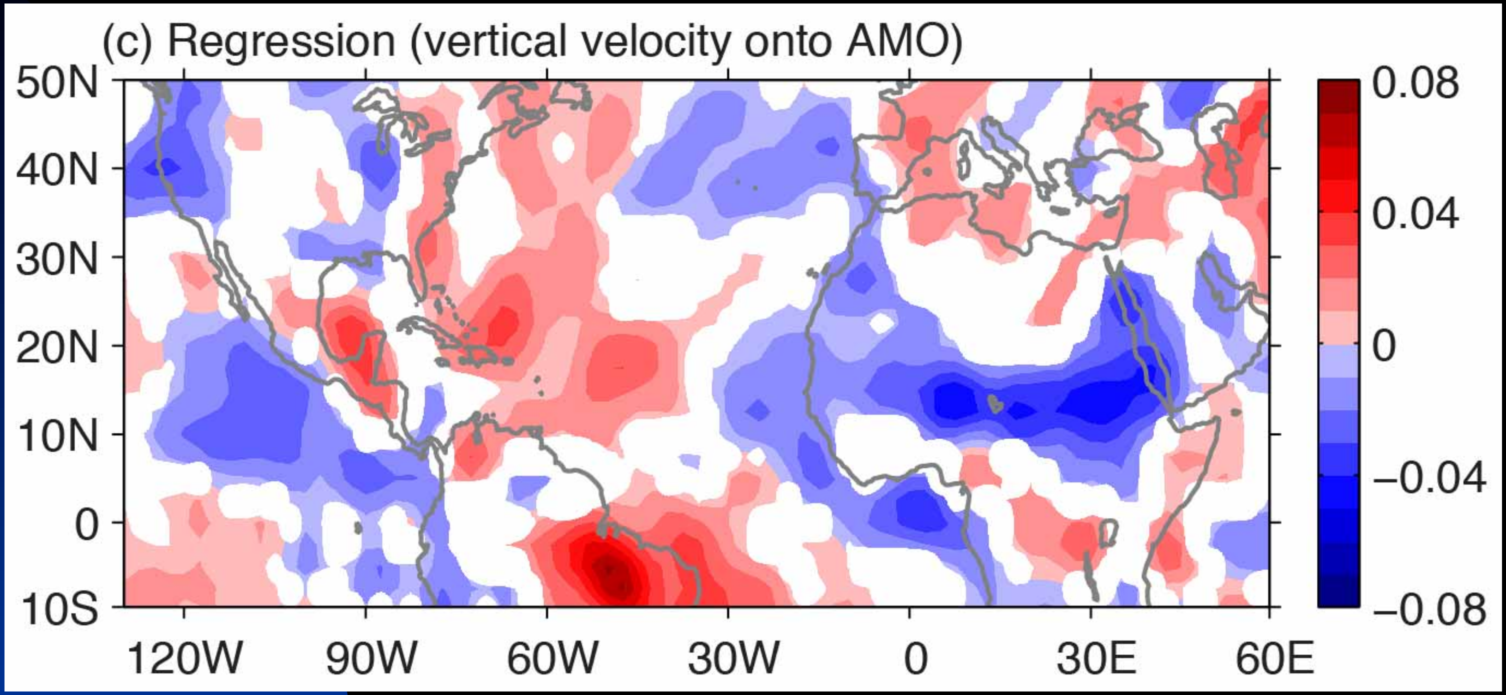
The spatial rainfall patterns related to the AMO and dust aerosol in the TNA



Rainfall related to the AMO

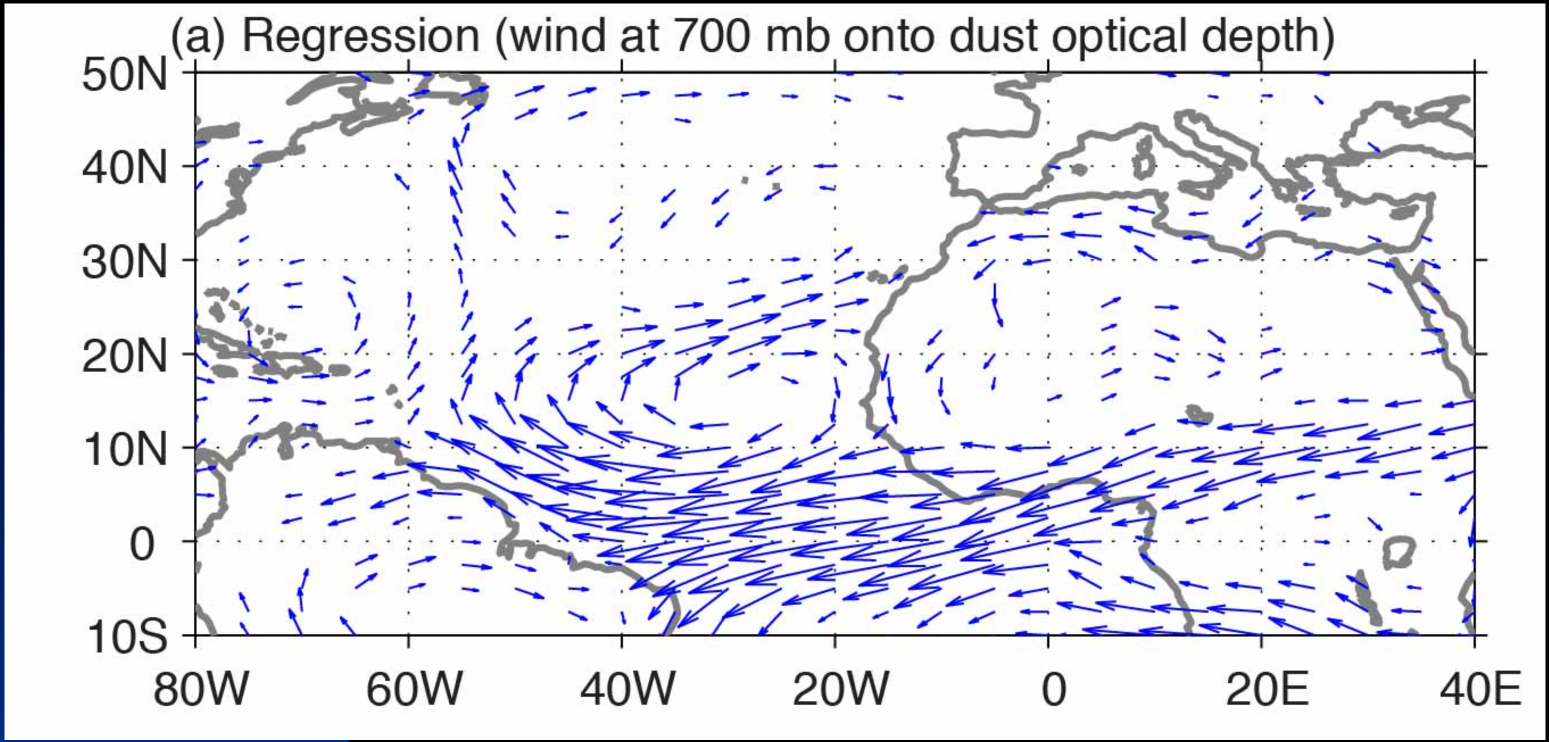
Rainfall related to TNA dust

Vertical velocity (at 500-hPa) associated with the AMO



A positive phase of the AMO leads to a northward shift of the ITCZ which is associated with a strengthening of the southwesterly monsoon and an upward motion in the Sahel.

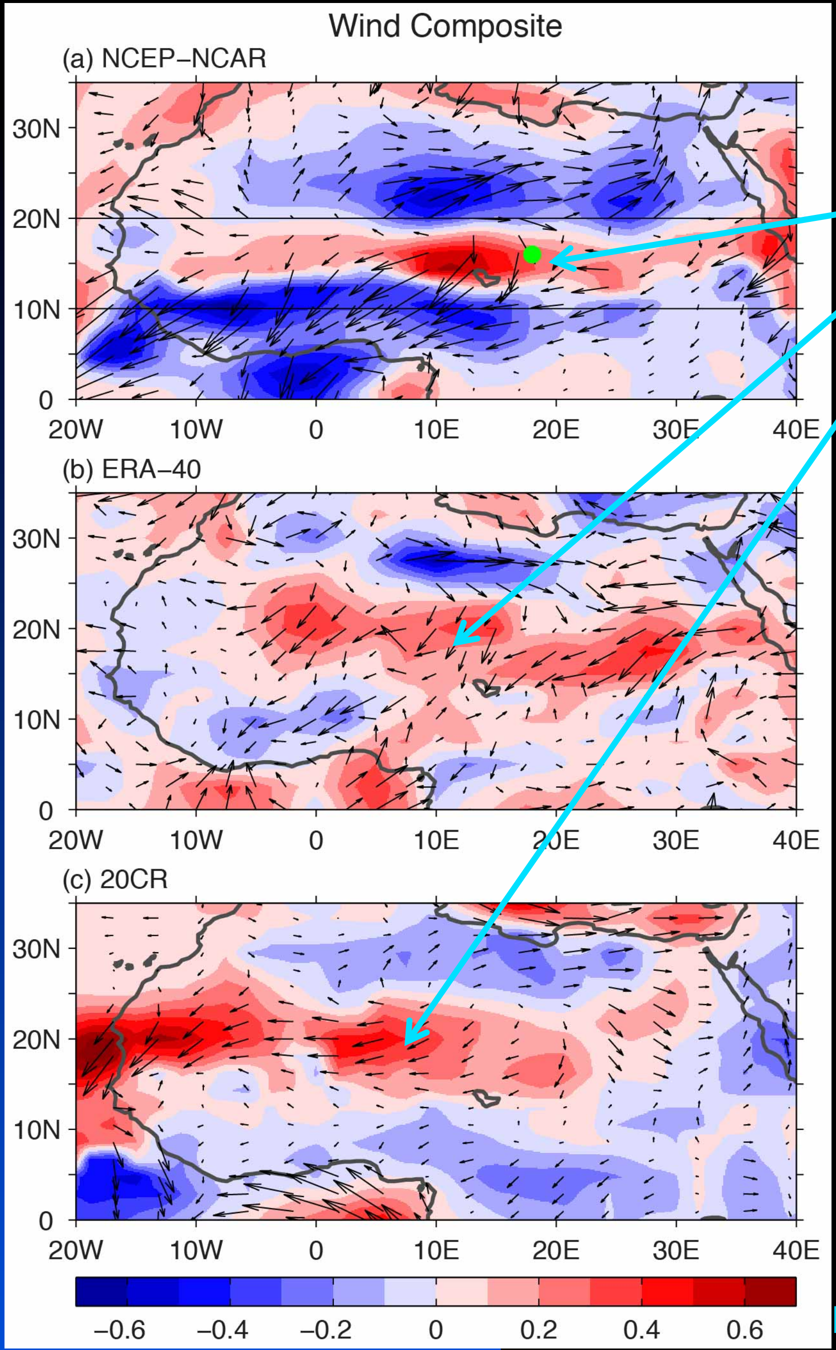
Relationship of winds at 700-hPa with dust aerosol



- The position inconsistency (maximum wind anomaly & dust band; maximum dust band is from 10°N-20°N) suggests that the dust changes in TNA could not be due to wind anomalies.

- We hypothesize that dust in TNA could be more due to (1) enhanced dust production in the Sahel and (2) transport by the mean zonal wind (instead of anomalies).

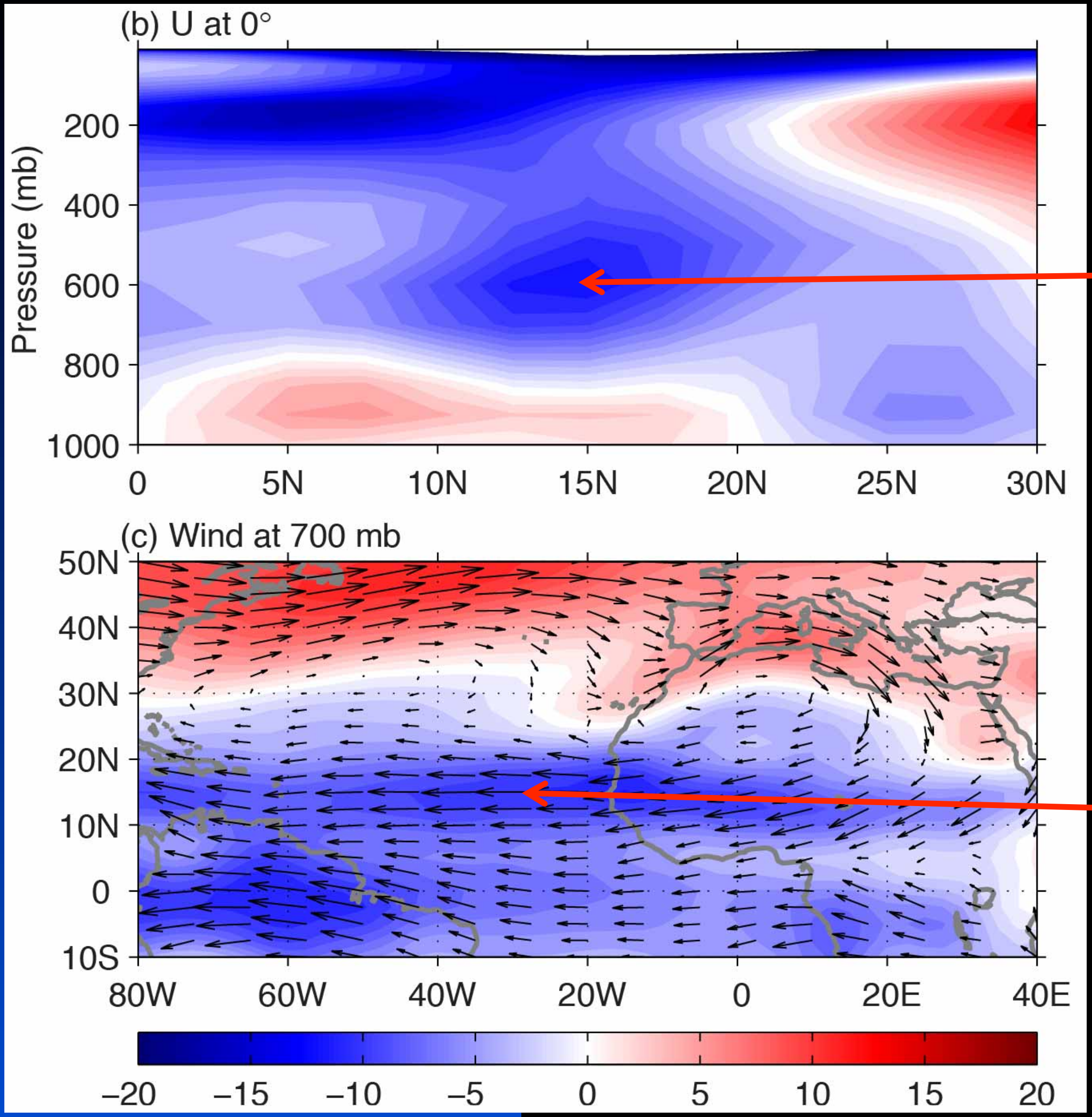
Wind difference between high & low dust years



An increased surface wind speed across the Sahel (dust production is proportional to wind speed cube: $\propto W^3$).

These indicate that dust production is enhanced in the Bodélé Depression during the cold phase of the AMO.

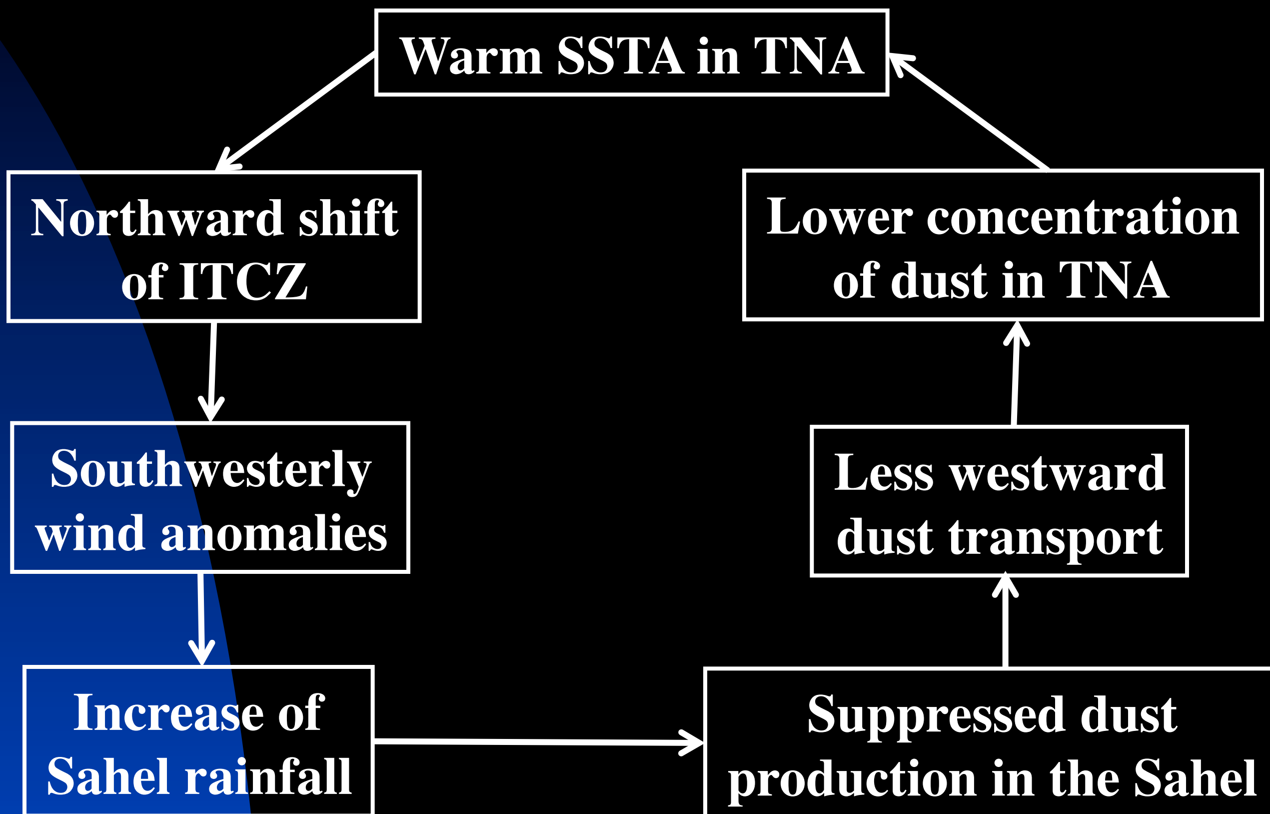
Dust in the Sahel is transported to the TNA by the mean zonal winds (instead of wind anomalies)



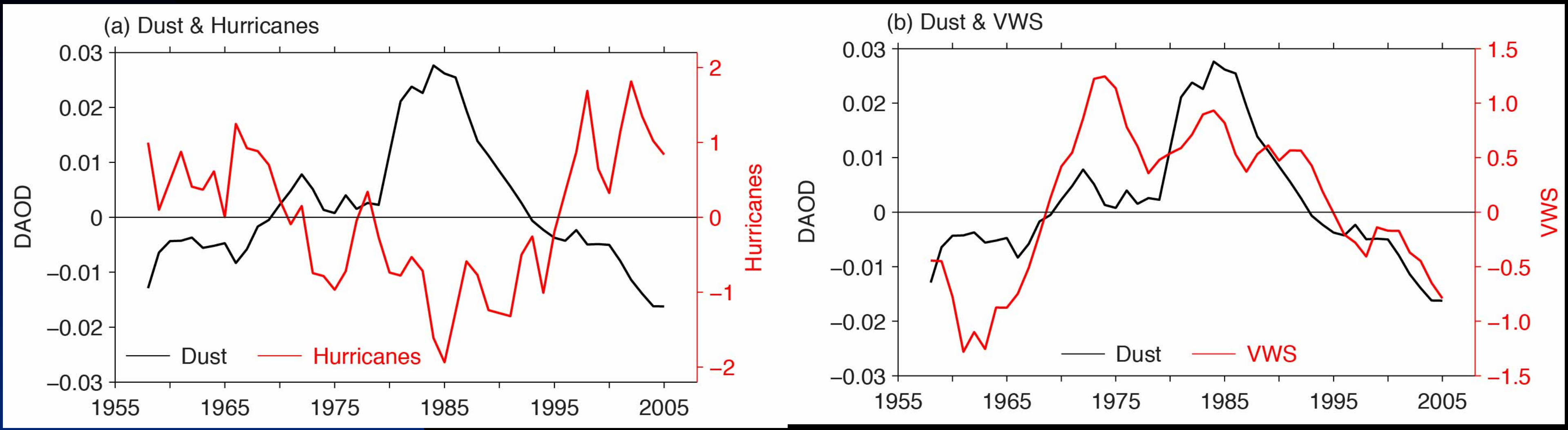
African easterly jet (AEJ)

Strong winds are across the entire TNA and consistent with the maximum dust band between 10°N-20°N.

A positive feedback between the AMO and dust via Sahel rainfall variability



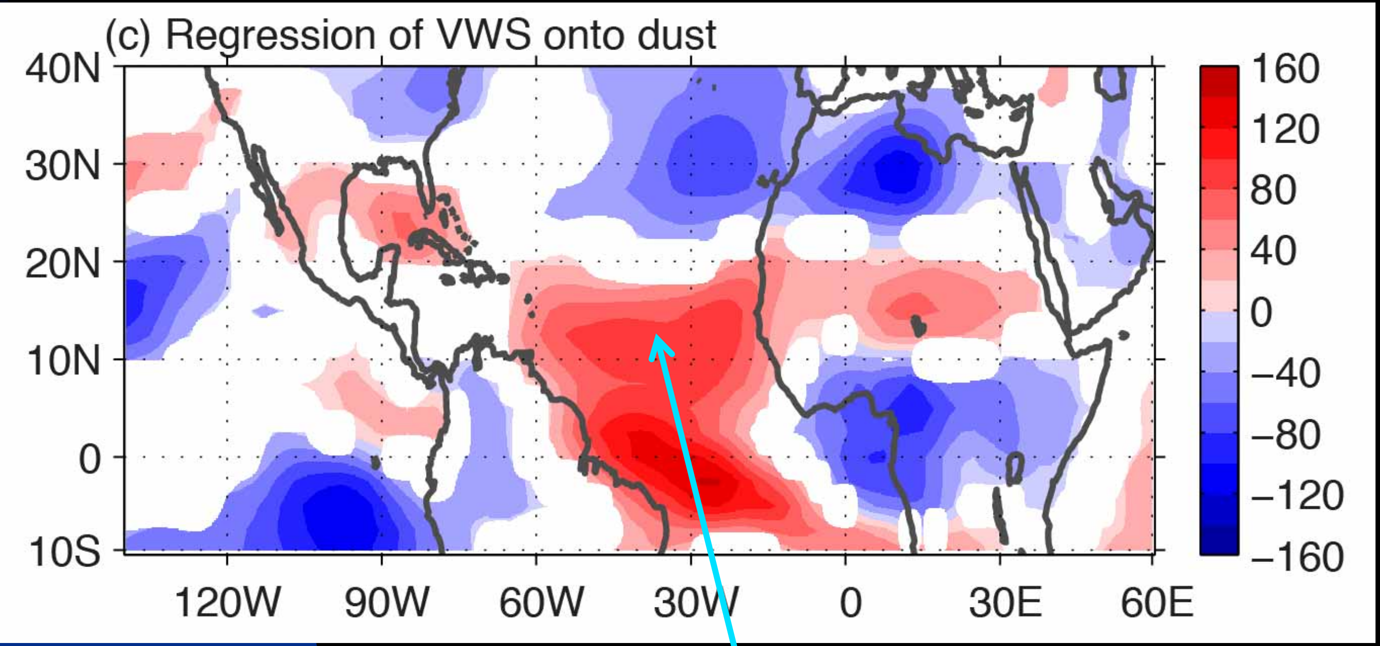
Dust and Hurricanes on Multidecadal Timescales



- **When dust concentration in TNA is low (high), the number of Atlantic hurricanes is more (less).**

- **This is because dust changes meridional air temperature gradient via dust-radiation processes and alters zonal winds (thermal wind balance) and then vertical wind shear (VWS).**

Dust and Hurricanes on Multidecadal Timescales



Strong VWS in the hurricane main development region (MDR)

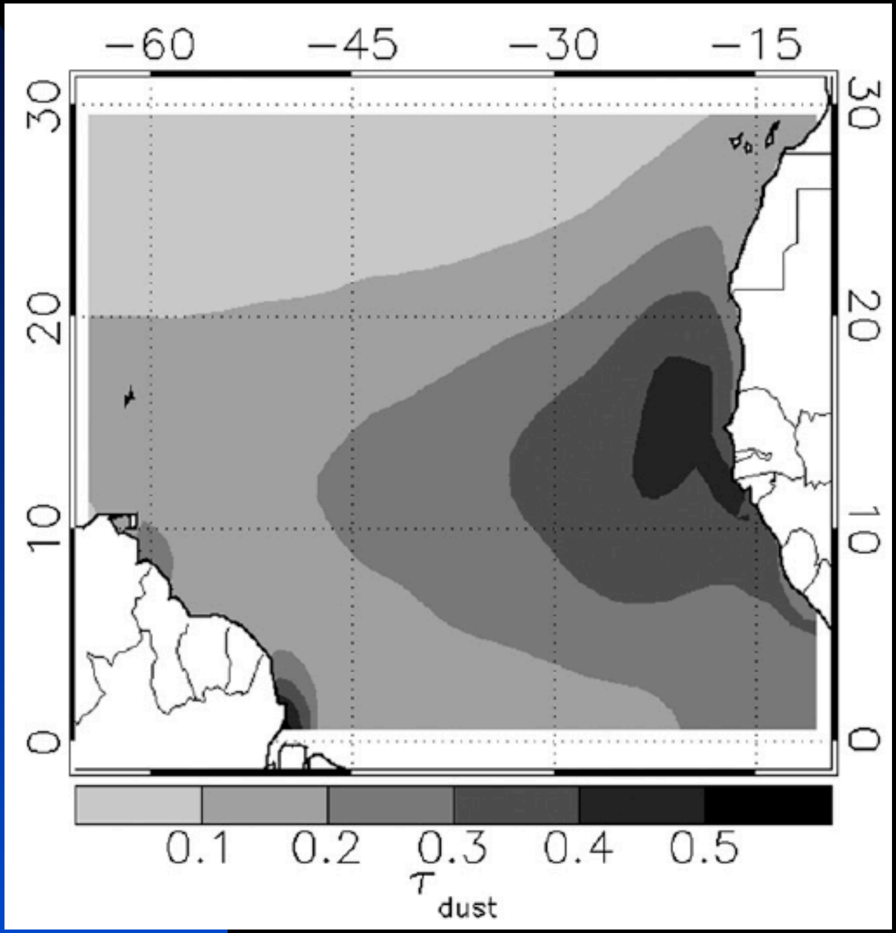
Summary

- This study shows a multidecadal co-variability of the AMO, dust in the TNA and rainfall in the Sahel.
- It suggests a novel mechanism for NA SST variability on multidecadal timescales: A positive feedback between the AMO and dust via Sahel rainfall.
- Dust varies inversely with the number of Atlantic hurricanes on multidecadal timescales due to dust-related VWS in the hurricane MDR.
- An implication of this study is that coupled models need to be able to simulate this aerosol-related feedback for a realistic climate simulation in the Atlantic.

Indirect Influences of Dust on Vertical Wind Shear

- Sahel rainfall (Landsea & Gray 1992).
- The Saharan air layer (Dunion & Velden 2004).
- North Atlantic SST (Goldenberg et al. 2001).
- Atlantic warm pool (Wang et al. 2006).
- Atlantic meridional mode (Vimont & Kossin 2007).

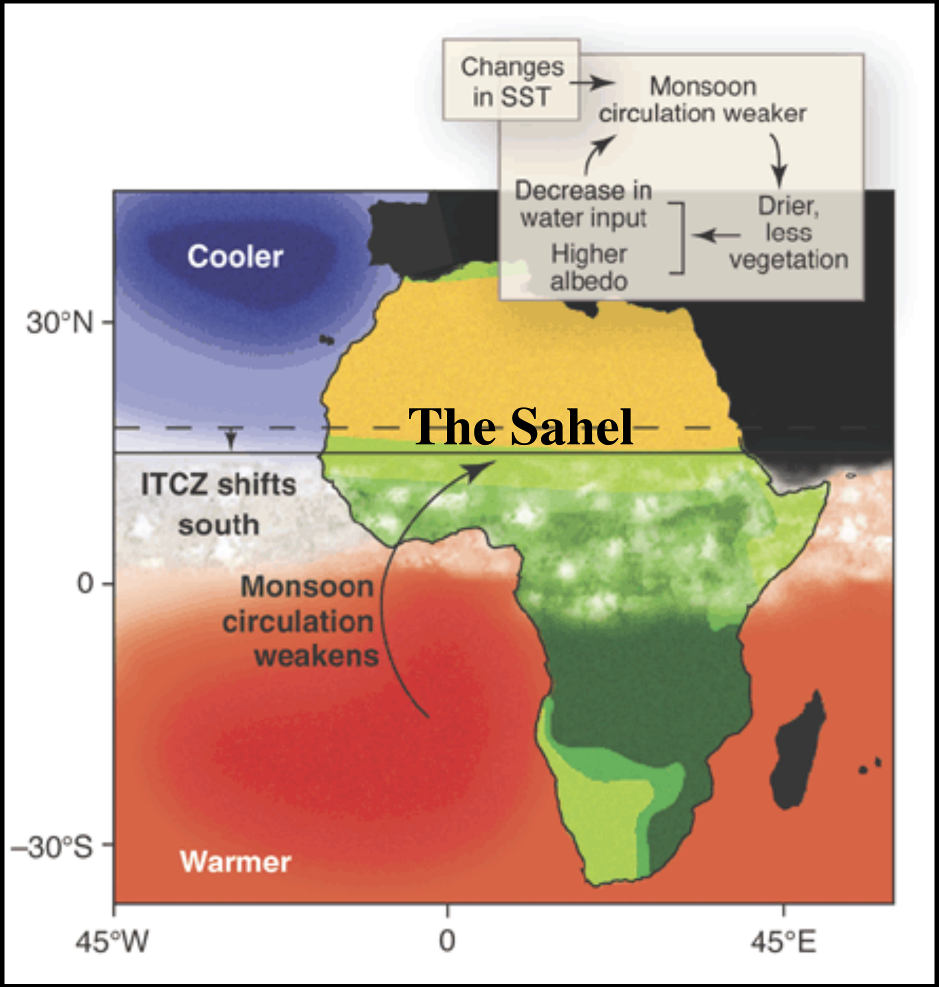
Dust data used in this study: Evan and Mukhopadhyay (2010) extended satellite-retrieved dust optical depth over the TNA from 1955-2008, using modern/historical data and a proxy record (crustal $^{4}H_{e}$ from a Porites coral) for atmospheric dust.



Climatology of dust for the period of 1955-2008

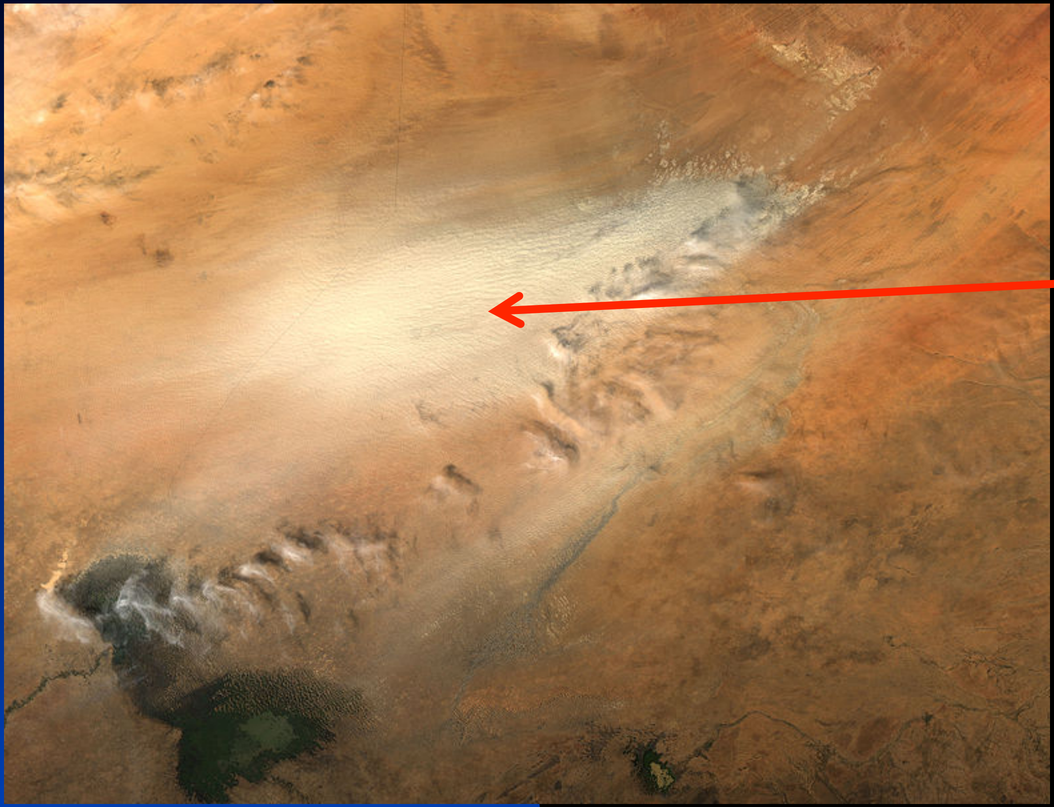
The Sahel region (10°N-20°N, 20°W-40°E)

The Sahel is a semi-arid tropical region



Sahel rainfall is forced by monsoon circulation associated with SST.

The Bodélé Depression (an area of 40,000 km^2 near 16°N, 18°E), located at the southern edge of the Sahara Desert in north central Africa, is the lowest point in Chad and the planet's largest single source of dust.



Dust storm was blowing on the afternoon of 18 November 2004 from the MODIS.

Two key requirements for deflation:

(1) strong surface winds,

(2) erodible sediment.

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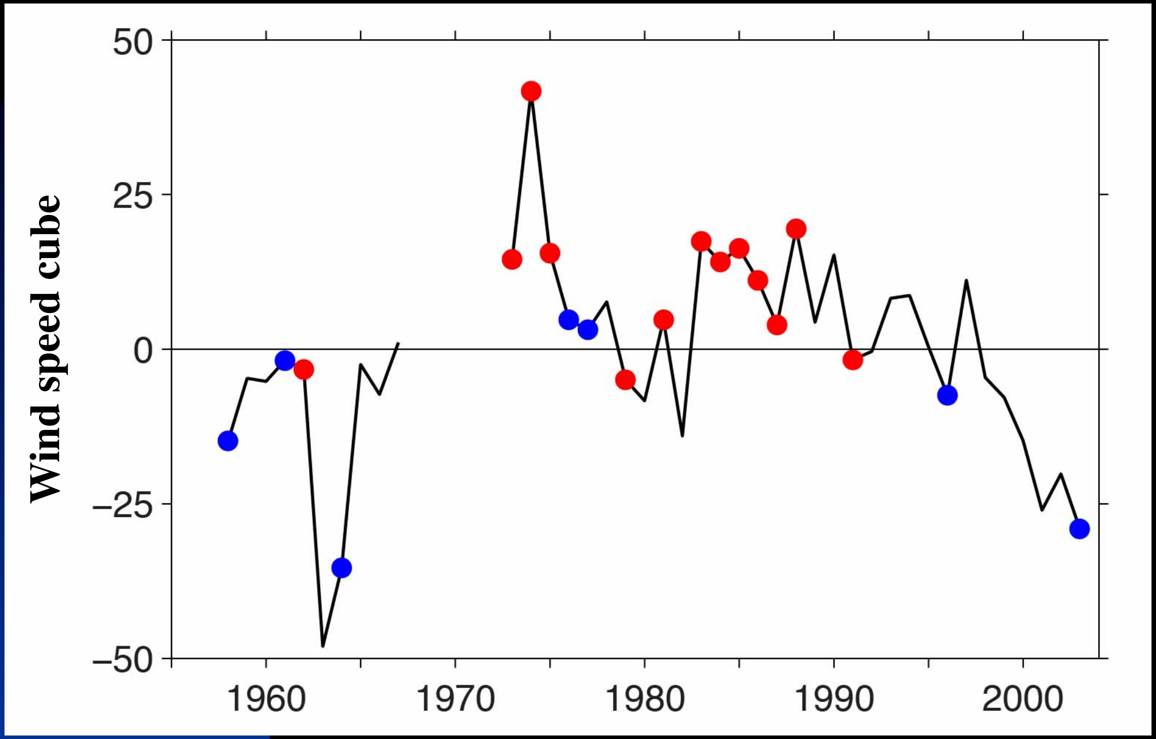
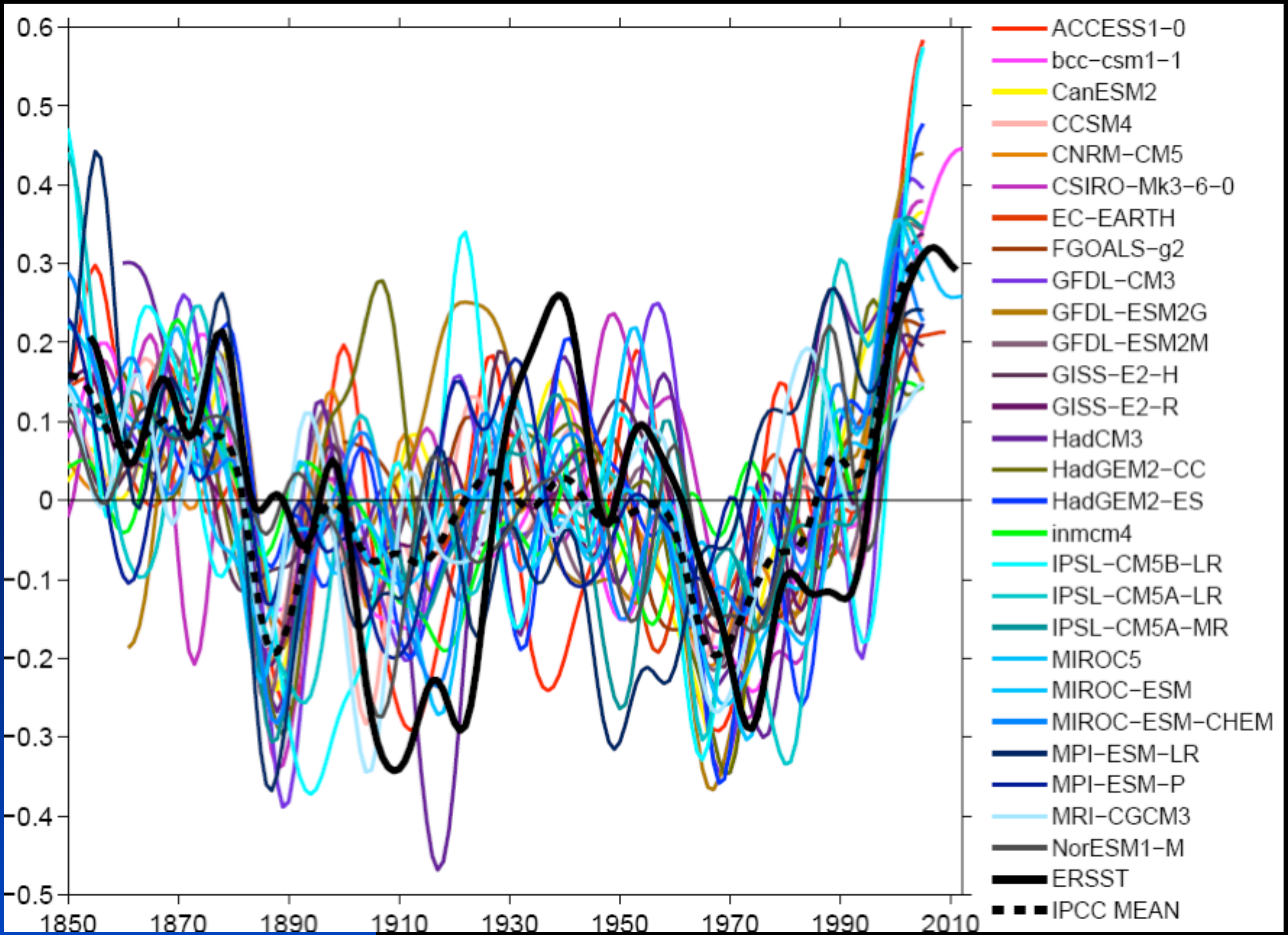
Annual average of the wind speed cube from the observed station data in the Western Sahel (dust production $\propto W^3$)



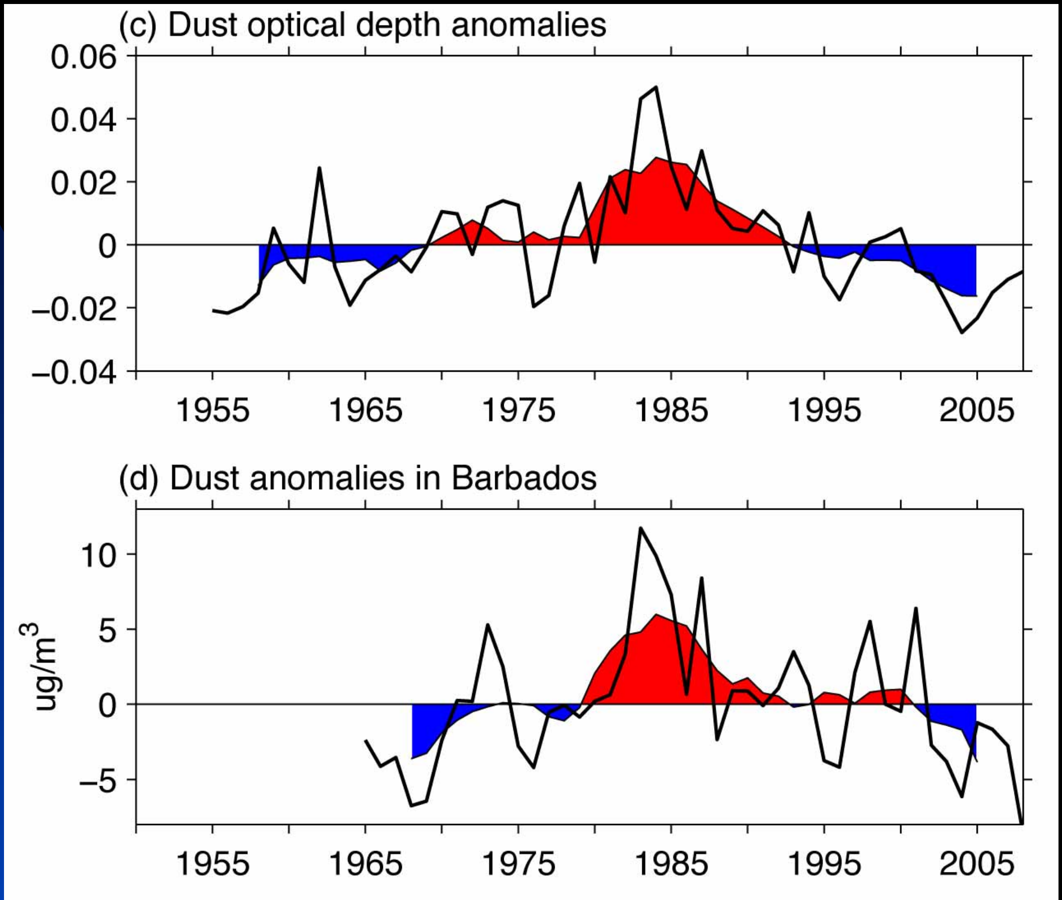
It also shows the AMO signal, consistent with the reanalysis products. All of these indicate that an increased wind speed (associated with the negative AMO and high TNA dust phases) produces more dust in the dust source region.

The AMO Simulated from 27 IPCC-AR5 Models



Zhang and Wang (submitted)

A comparison with the station dust time series observed on the island of Barbados since 1965



Correlation is 0.70 for the yearly data and 0.84 for the 7-yr running mean

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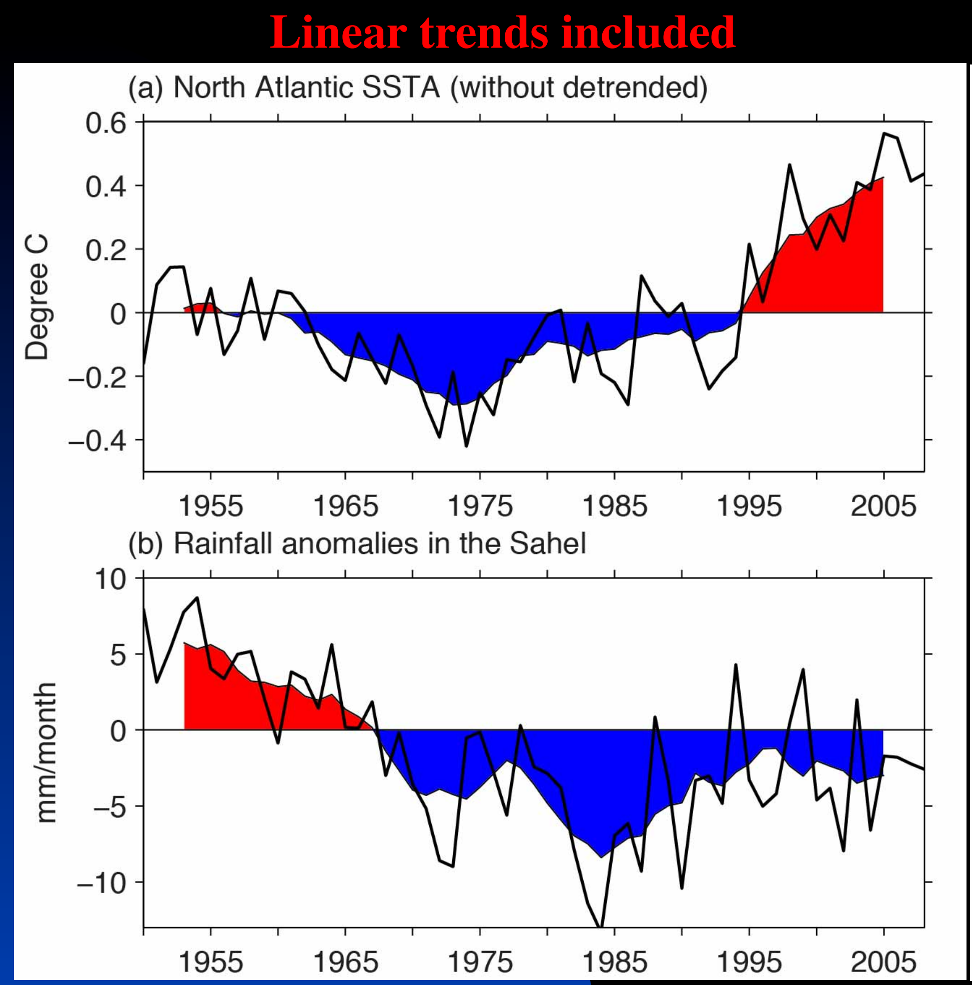
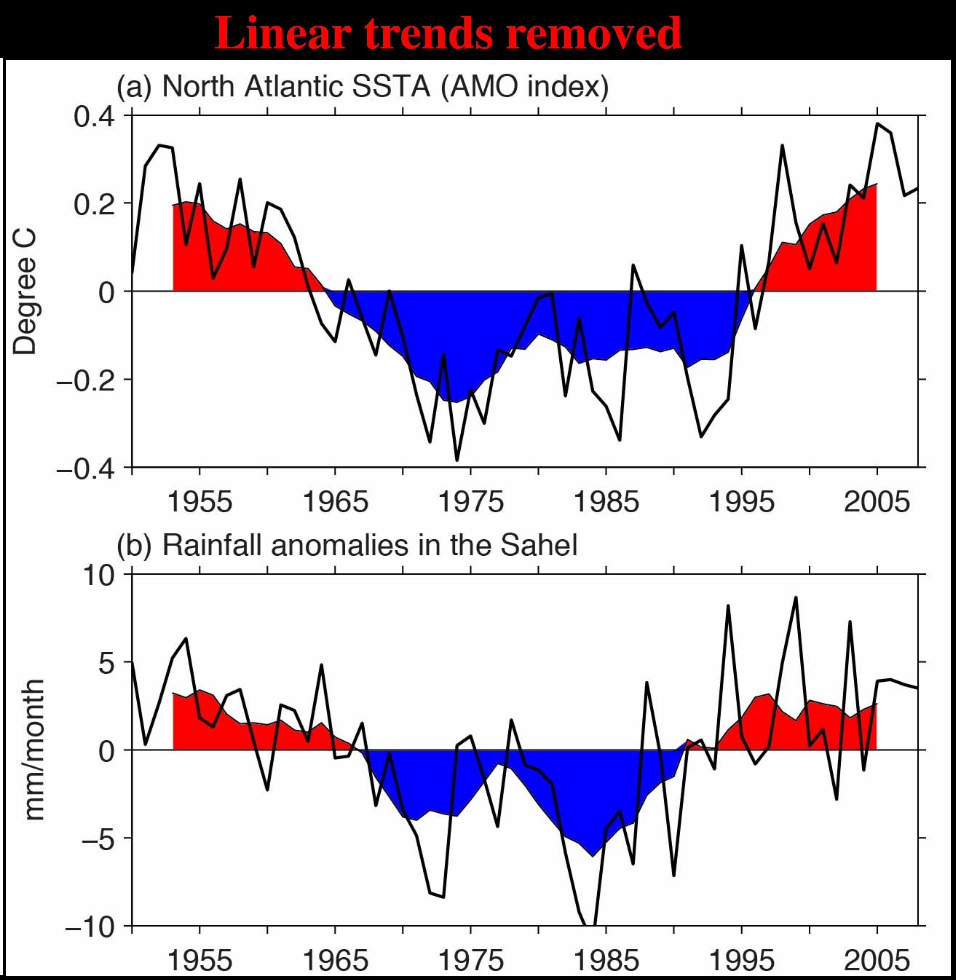
What are roles of global warming?

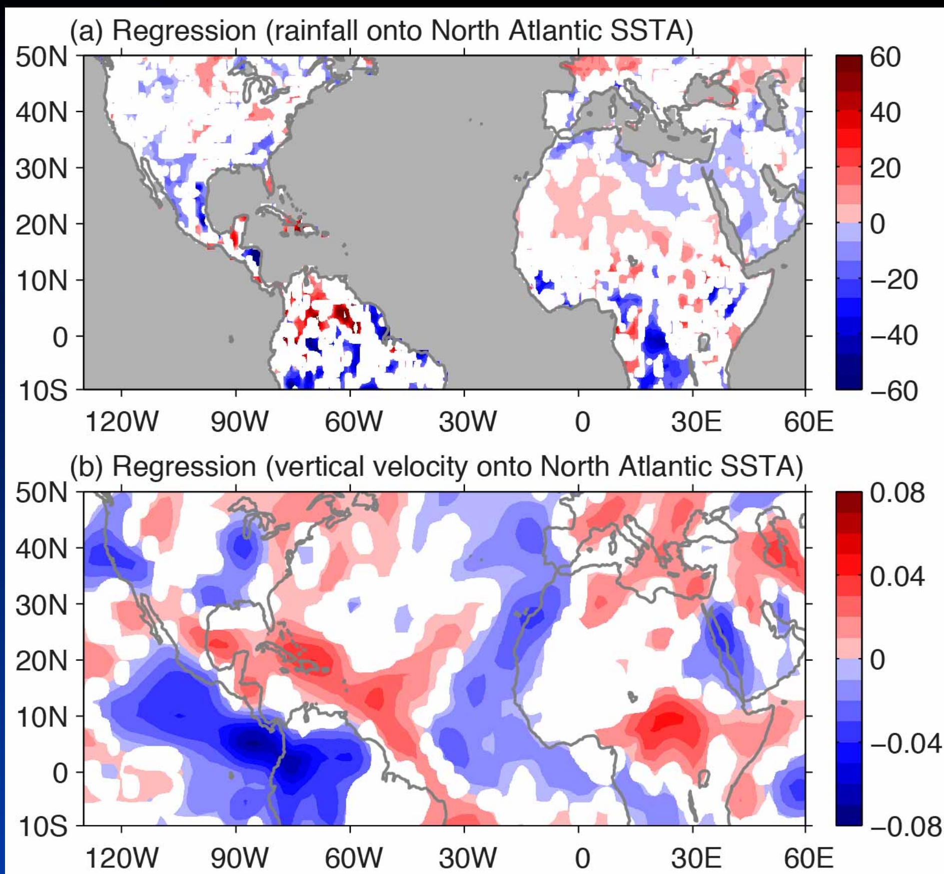




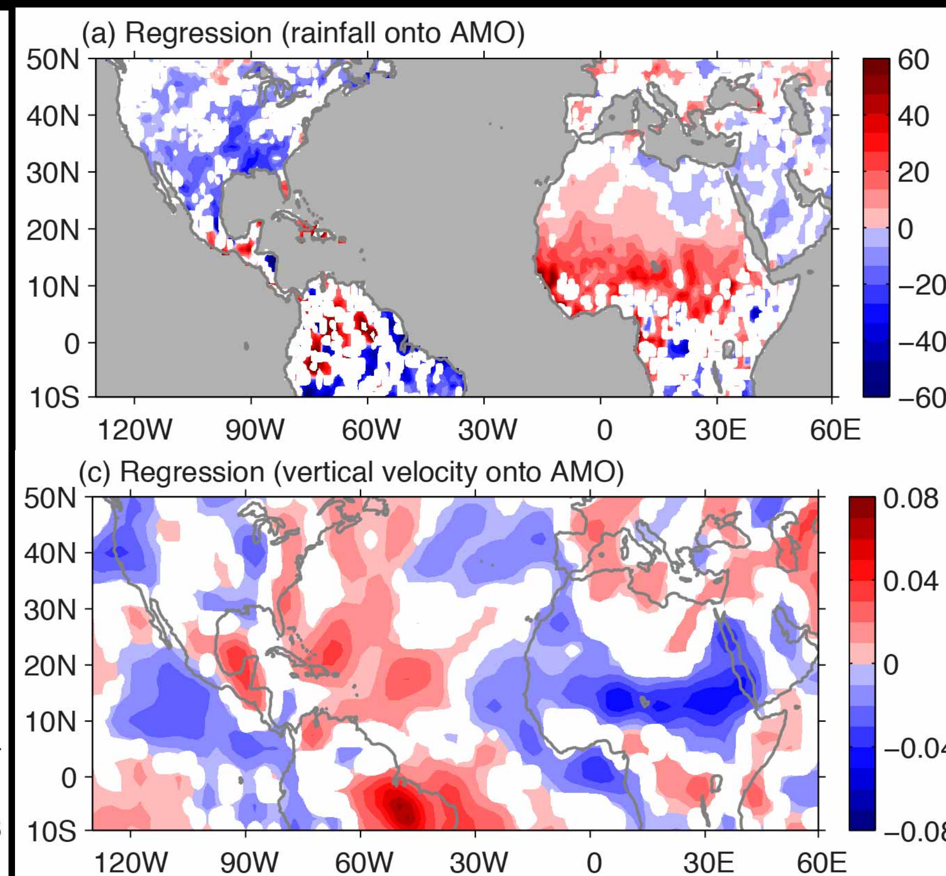
The warming trend is associated with a reduction of Sahel rainfall, whereas the warm phase of the AMO after the early 1990s tends to increase Sahel rainfall.

What are roles of global warming?

Linear trends included

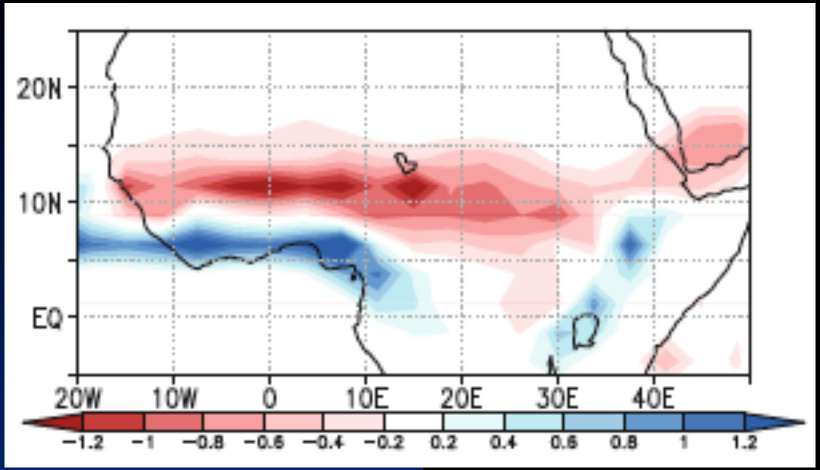


Linear trends removed

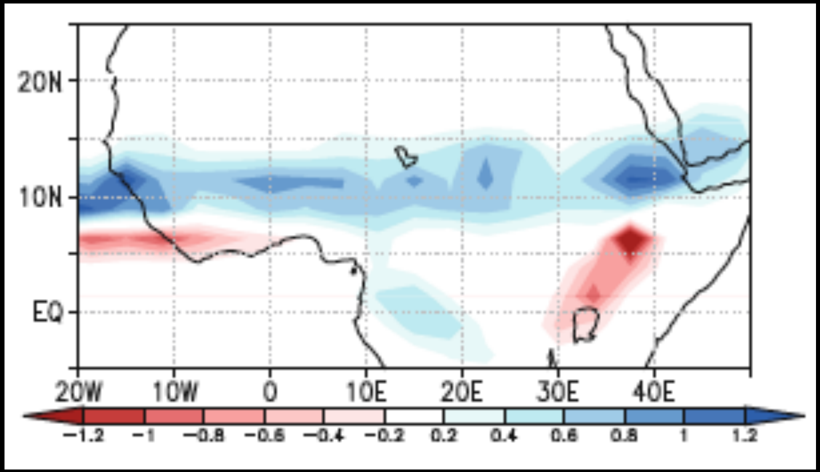


The warming trend is associated with a reduction of Sahel rainfall, whereas the warm phase of the AMO after the early 1990s tends to increase Sahel rainfall.

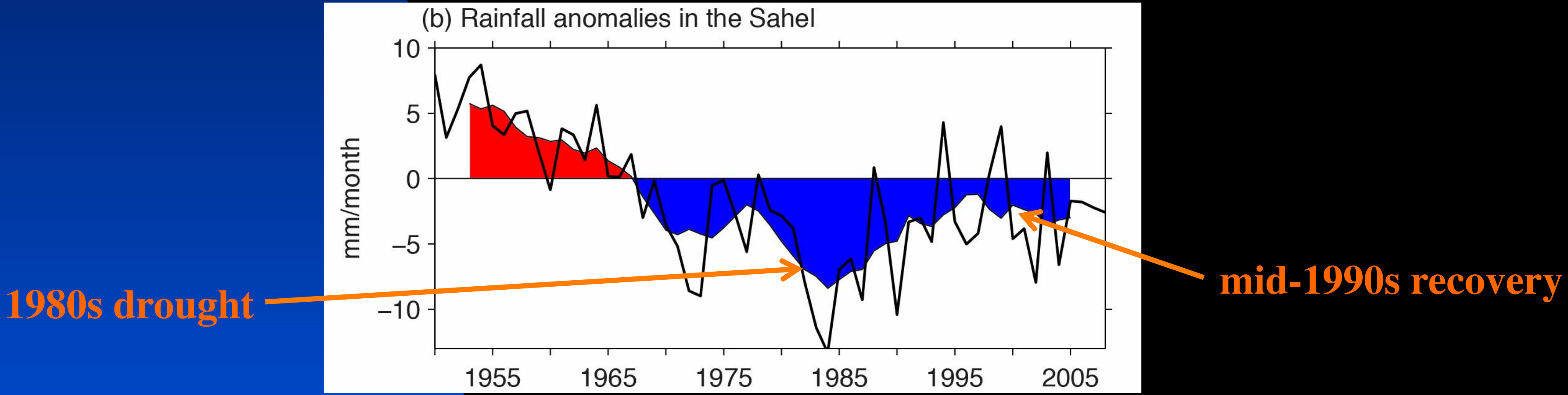
A recent modeling study of SST contribution to 1980s drought (mid-1990s recovery) in West Africa (Mohino et al. 2011, *CD*)



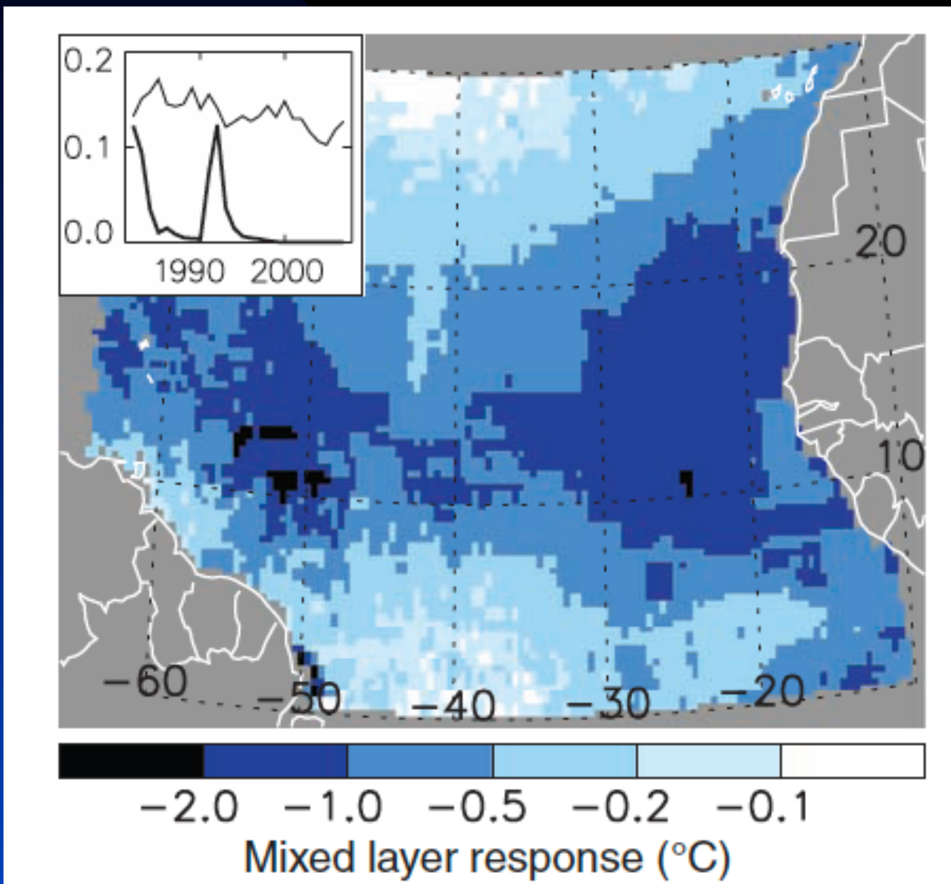
GW: 10% (-20%)



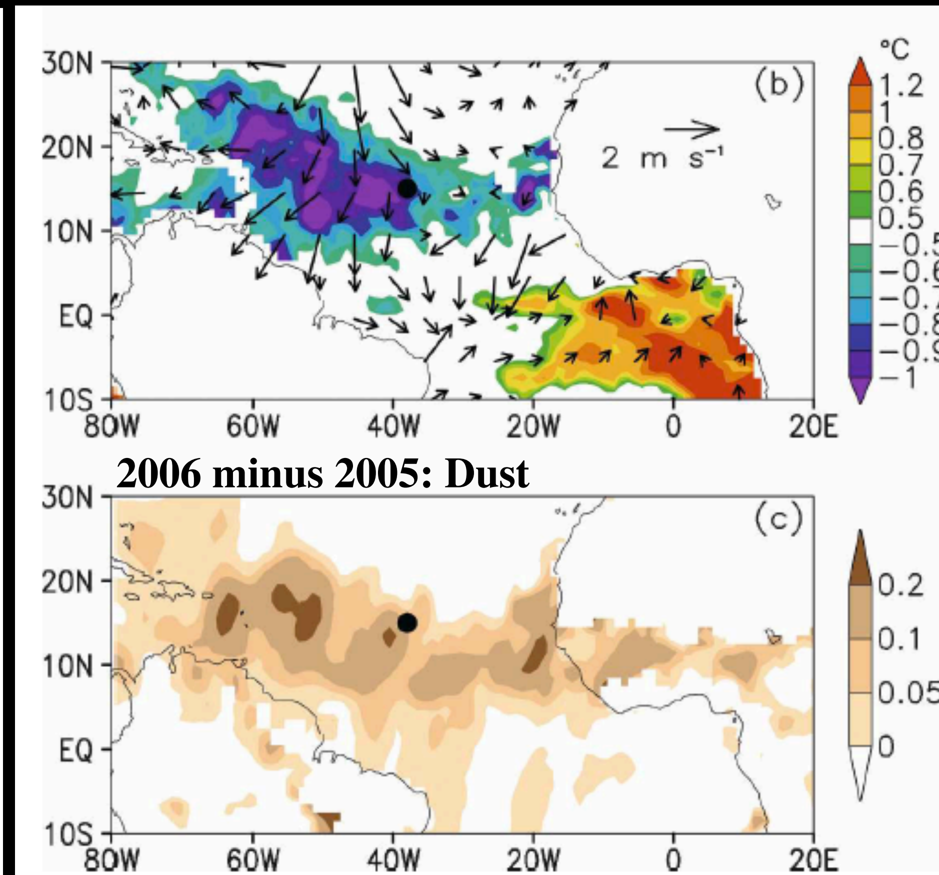
AMO: 50% (80%)



Role of dust in the ocean: Some studies show that high (low) concentration of dust in the TNA cools (warms) the TNA.



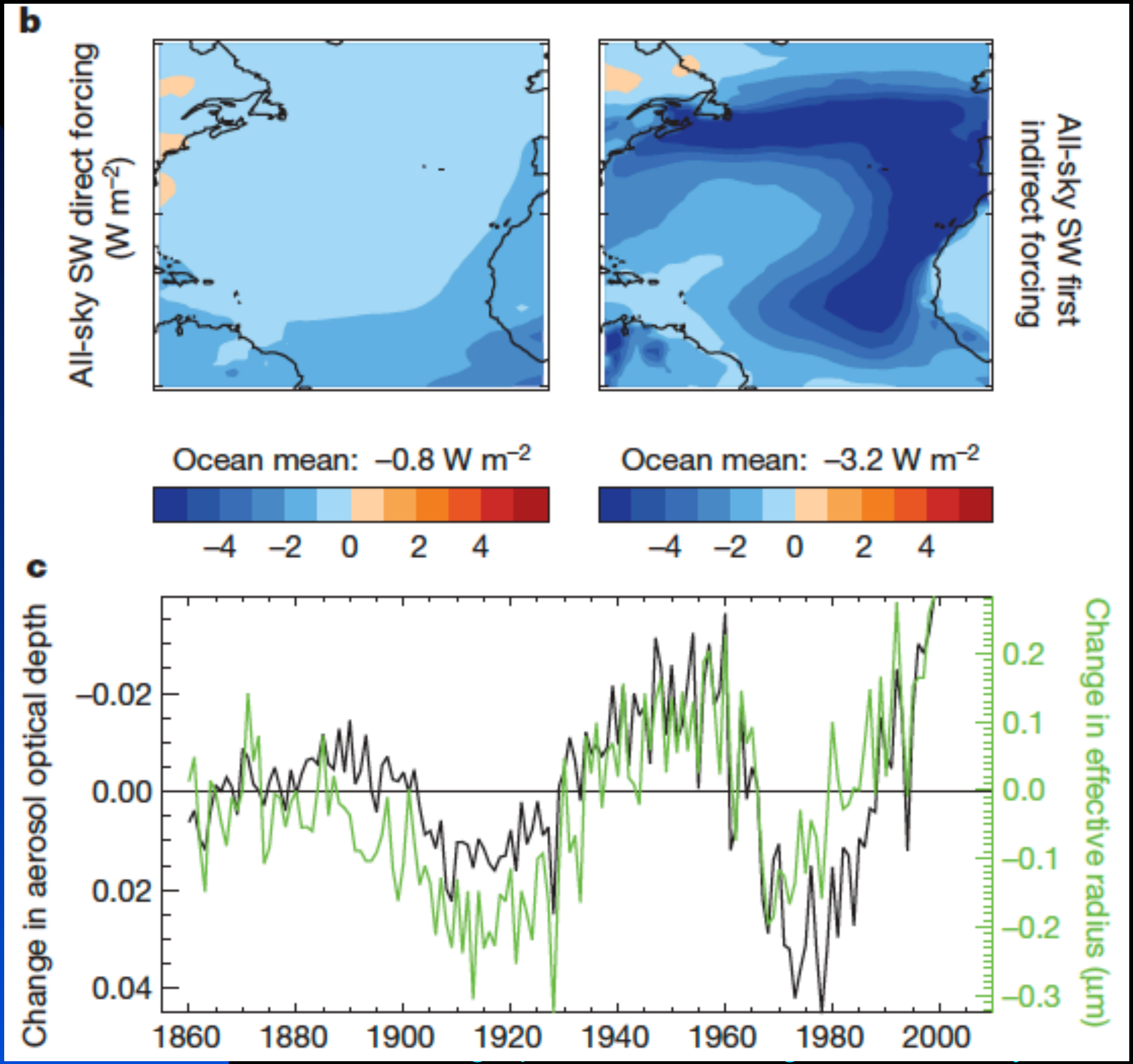
Evan et al. (2009, *Science*)



Foltz & McPhaden (2008, *JC*)

Using HadGEM2-ES climate model, Booth et al. (2012, *Nature*) focus on the forcing by volcanoes and anthropogenic aerosols. They argue that the AMO is not an internal variability.

SW forcing induced by direct effect (absorb & scatter radiation)



SW forcing induced by first indirect effect (aerosols-cloud)

However, the simulations by Booth et al. (2012, *Nature*) fail to capture dust concentration in the North Atlantic on multidecadal timescales, i.e., no the AMO signal. The authors state that this is due to the lack of a common coherent dust response in the model.